Elemental analysis using LIBS for Martian Moons Exploration (MMX)

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Phobos and Deimos are the two satellites of Mars. There are two major hypotheses for their origin: asteroid capture [Hunten, 1979] and a giant impact [Rosenblatt et al. 2016]. JAXA's Martian Moons Exploration (MMX) is planned to be a sample return mission from Phobos. One of the main goals of MMX is to determine the origin of the two Martian moons. To determine the origin of the moons, it is necessary for the returned sample to contain information on satellite formation. Therefore, we should identify the uniformity or nonuniformity of the distribution of surface material on Phobos. We can obtain the averaged elemental composition using a gamma-ray and neutron spectrometer (GNS) as the nominal instruments, but the distribution of the elemental composition cannot be obtained with a resolution of about 10 mm. We propose using laser-induced breakdown spectroscopy (LIBS) that can perform an elemental analysis with a spatial resolution of 1 mm at a distance of 1 m or more. Because the MMX operating time is limited to be about 1 hour, a LIBS instrument that can perform measurements in tens of seconds could be suitable onboard MMX.

Understanding the heterogeneity of the materials around the sampling site is important for providing the geological context of the returned sample. Thus, we conducted an experiment to demonstrate that we can determine whether the Phobos surface composition resembles that of Martian meteorites or that of a carbonaceous chondrite in a short time by LIBS. We used a small laser with an output of about 12 mJ/pulse and a wavelength of 1534 nm. For the data acquired with the spectrometer, the range of wavelengths from about 380 nm to 800 nm was used for analysis. The distances between the lens to converge the laser beam and the sample and between the condensing lens of the spectrometer and the sample were both 1.5 m. The effective diameter of the light collection optical system was 20 mm. The samples were placed in a vacuum chamber, which was evacuated to 10^{-3} Pa. We verified the feasibility of the LIBS measurement, including signal-to-noise ratio, under realistic conditions. The samples were Allende (a carbonaceous chondrite), NWA1068 (a Martian meteorite), and Zagami (a Martian meteorite). The samples were irradiated 150 times at each measurement point at a frequency of 10 Hz. The exposure time of the spectrometer was 1 s. We measured 16 points per a sample to obtain the bulk composition of the meteorites. The emission spectra of the major elements, Fe, Ca, Al, Mg, Si, and Ti, were detected in the average spectra of the 16 measurement points. By subtracting the spectra of the Martian meteorites from that of the carbonaceous chondrite, we found that the intensity of the emission lines of Fe and Mg, which are abundant in the Allende meteorite, exhibited positive values. In contrast, the intensity of the emission lines of Al and Ca, which are abundant in the NWA1068 and the Zagami meteorites, exhibited negative values. These results showed that LIBS is able to distinguish between asteroid-like and Martian-like materials.

Next, we evaluated whether LIBS was able to conduct this measurement within the MMX operating time on the surface. It was assumed that the focus adjustment and image acquisition takes 30 s and moving from one measurement point to another takes 20 s. The laser irradiation frequency was assumed to be 2 Hz to reduce electric power consumption. With these times, it required about 35 minutes to conduct the data acquisition as in our experiment (i.e., measuring 16 points with 150 laser irradiations per point). This indicates that LIBS is able to obtain sufficient data within the operating time of the lander. Thus, our results suggest that LIBS can reveal whether Phobos is similar to the asteroids or to Mars.

In this presentation, we will also report on the production of an engineering model and the results of

experiments using it.

Keywords: LIBS, Martian Moons Exploration (MMX), in situ analysis

